EFFECT OF TWO NITROGEN SOURCES ON BROMEGRASS PRODUCTION AND SOIL pH

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INTRODUCTION

Grasses such as bromegrass require large amounts of nitrogen to maintain a high level of production. Although response of grasses to nitrogen is strongly related to moisture conditions, substantial yield increases can be obtained from adequate rates of fertilizer N under the relatively dry conditions prevailing in west-central Saskatchewan. Moisture conditions are generally more favorable for forage production in northern Saskatchewan, and larger and more consistent increases in yields of grasses are usually obtained with application of nitrogen fertilizers.

Urea is now a widely used granular nitrogen fertilizer in Western Canada, gradually replacing ammonium nitrate. When applied to soils by banding or broadcasting with immediate, thorough incorporation, it is generally equal in effectiveness to ammonium nitrate in most soils. However, when broadcast on the soil surface, which is the usual practice when fertilizing perennial forage crops, effectiveness may be lower. Some studies have shown no consistent or significant difference between urea and other N sources for grasses (Tesar 1978; Lamond, et al. 1979; Smith and Chalk 1980). Other workers have shown lower yield increases and lower N recoveries from urea than from ammonium nitrate or other N sources when the fertilizers were surface applied on grass swards (Burton and Jackson 1962; Ukrainetz 1969; Power et al. 1972). Urea is frequently as effective as ammonium nitrate at low rates, but not at high rates (Power 1974).

The lower effectiveness of surface-applied urea is generally attributed to loss of N through volatilization of ammonia following hydrolysis of the urea (Volk 1959; Power, et al. 1972). Under certain conditions these losses can amount to more than 50% of the N applied (Simpson 1968) Ammonia-N losses from surface-applied fertilizers increase with higher temperatures and lower humidity, and on soils having coarse texture, low C.E.C., high pH and low water contents (Terman 1979). Under dryland conditions in western Saskatchewan, where leaching losses of applied fertilizer may not be a significant problem, it may be practical to apply a high rate of N fertilizer once to established stands of perennial grass, with PKS if required, to supply the crop's requirements for a period of several years. Relatively little information is available on the efficiency of N fertilizers for grasses when applied once at high rates on established stands for residual effect as compared to lower annual rates over a long term period. Leyshon and Kilcher (1977) found that a single application of 933 kg N/ha as ammonium nitrate increased yields of crested wheatgrass and Russian wild ryegrass for at least 10 years in southwestern Saskatchewan. Lutwick and Smith (1979) showed that when a relatively high rate of

N as ammonium nitrate was applied every year for 4 years, the total yields of several grasses were only slightly greater than where N was applied once at the beginning of the experiment. However, with a single high rate application the highest yields were generally obtained in the year of application with decreasing yields in subsequent years.

Information is lacking on the relative efficiencies of urea and ammonium nitrate when surface-applied once at high rates or annually at lower rates to established stands of perennial grasses on different soil types in Western Canada.

There are potential disadvantages to application of very high rates of N fertilizers to grassland. In addition to the losses of N which may occur through volatilization as NH_3, particularly where urea is the source of N, leaching losses may also be greater than where low rates of N are applied. Excessively high rates of N fertilizers can result in the accumulation of toxic levels of NO_3-N in forage. Generally, rates of applied N below 225 kg/ha seldom increase plant NO_3-N to toxic levels (Ukrainetz 1969; Smith and Lutwick 1974; Meyer, et al. 1977). Under certain conditions considerably higher rates of N can be applied without producing dangerous levels of plant NO_3-N. Chances of high NO_3-N content in forage rise appreciably if N supply reaches or exceeds about 500 kg/ha (Deinum and Sibma 1980). The application of high rates of N fertilizers, whether applied once or annually, to maintain high yields of pure grass stands could lead to soil acidification and a decrease in productivity. The acidity is produced by the nitrification of NH_4-containing and NH_4-producing fertilizers, and by the leaching of NO_3, SO_4, and Cl ions from fertilizers (Gasser 1973). Relatively high rates of N fertilizers applied annually have been shown to significantly lower soil pH during fairly short periods (Cairns 1971; Jolley and Pierre 1977; Fox and Hoffman 1981; Hoyt and Hennig 1982). Relatively small amounts of N- and S-containing fertilizers applied over 40 years resulted in increase in soil acidity sufficient to reduce alfalfa production (McCoy and Webster 1977).

The objectives of this study were to determine the effectiveness of ammonium nitrate and urea when applied once or annually at several rates over a period of several years for bromegrass dry matter and protein production on two soil types, and to determine the effects of the N applications on soil pH.

METHODS AND MATERIALS

Urea and ammonium nitrate were broadcast once on relatively old, established stands of bromegrass at rates of 100, 200, 400, and 800 kg N/ha, and an additional rate of 1000 kg N/ha of ammonium nitrate, or annually at 50, 100, and 200 kg N/ha during a period of five years, 1977-81. Phosphorus, K, and S were applied to the plots at uniform rates at the beginning of the experiment in 1976, and again in 1979 and 1981. Checks received no fertilizer. Similar experiments were carried out on a Dark Brown Chernozemic Scott loam and a Gray Luvisolic Loon River loam, briefly described in Table 1.

Table 1. Some characteristics of the soils*

Soil type	Original pH**	Organic matter	C.E.C. meq/100g %	Sand %	Silt %	Clay %
Scott loam (eluviated Chernozem)	5.5	4.8	17.5	41.6	46.8	11.6
Loon River loam (Luvisol)	6.2	2.4	10.4	45.3	26.7	28.0

* 0-15 cm depth
** 0.01 M $CaCl_2$

Soil samples were taken from the plots each year prior to fertilizer applications for moisture determination and chemical analysis. Soil pH was determined in 0.01 M $CaCl_2$ (1:2 ratio) on samples taken at the beginning of the experiment and in April of the fifth year. Each fertilizer treatment was applied on plots 1.85 m X 6.15 m, and the treatments were arranged in a randomized block design with four replicates. Bromegrass yields were determined by cutting a 60 cm strip through the length of each plot at the flowering stage, and drying a representative sub-sample to convert the yields to a dry matter basis. Only one cut per year was obtained except in 1977 at Loon Lake when there was sufficient regrowth for two cuts. The dried forage was ground in a Wiley Mill, and analyzed for N, P, and NO_3-N contents. Protein content was obtained by multiplying total N X 6.25.

Precipitation was recorded at both plot sites each year (Table 2).

Table 2. Monthly precipitation for the years 1977-81 at bromegrass fertilizer study locations.

Month	1977	1978	1979	1980	1981
	Precipitation - mm				
		Scott loam site			
April	7.4	71.3	37.1	9.0	26.0
May	110.2	37.7	29.0	15.0	34.8
June	12.4	40.6	79.5	92.4	57.9
July	28.0	24.9	89.7	45.9	81.9
August	27.1	41.1	27.2	47.2	2.8
September	45.8	40.9	12.7	31.4	16.2
October	2.8	18.6	13.3	8.0	11.9
		Loon River loam site			
April	11.4	63.2	32.4	0.4	49.0
May	88.8	70.0	19.5	8.2	7.0
June	71.9	43.7	83.2	54.0	60.8
July	100.5	36.1	70.2	44.8	67.6
August	45.6	77.4	47.0	119.4	27.0
September	58.7	61.5	58.2	56.4	11.2
October	15.0	5.9	8.1	7.8	19.2

RESULTS AND DISCUSSION

Hay yields

Yields of bromegrass hay (dry matter) for each of the five years (1977-81) on plots which received one application of urea and ammonium nitrate on the two soils are shown in Figures 1 and 2.

On Scott loam (Figure 1) urea and ammonium nitrate produced similar yields when applied at 100 kg N/ha, and there was very little difference between the two sources when applied at 800 kg N/ha. At 200 and 400 kg N/ha ammonium nitrate produced somewhat higher yields than urea. Where 100 kg N/ha was applied once yields dropped sharply in the second, third and fourth years. At the 200 N rate yields on urea plots also decreased in years 2, 3 and 4, but at a lesser rate than on the 100 N plots. Bromegrass yields on the 200 N ammonium nitrate (AN) plots increased in the second year

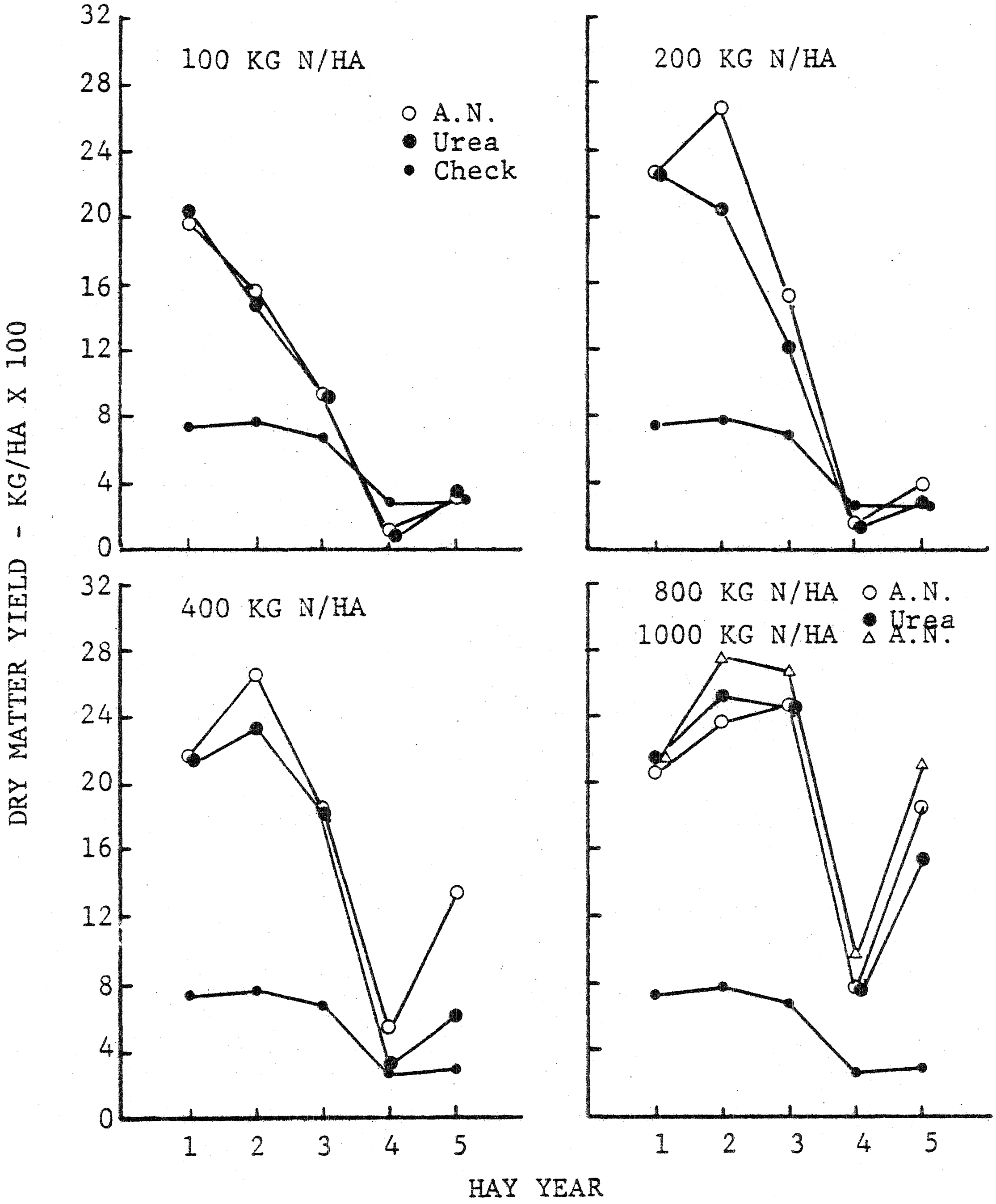

Figure 1. Effect of one broadcast application of ammonium nitrate and urea at several rates on annual yields of bromegrass hay over a 5-year period on Scott loam (1977-81).

before dropping sharply in the third and fourth. Where 400 kg N was applied yields for both urea and AN increased in the second year then decreased in the third and fourth. At 800 kg N yields were maintained for the first 3 years then declined in the 4th. The 1000 kg N/ha rate of AN produced the highest yield in all years, but the yearly trend in yields was similar to the 800 kg N rate. Lowest yields were obtained at all rates of N in 1980, year 4, resulting from low precipitation during the months of April and May. In this year yields on the 100 and 200 kg N/ha plots were below the check.

On Loon River loam (Figure 2) the pattern of yields was quite similar to that on the Scott loam, except that yields were generally higher, there was a larger increase in yield with increasing rate of N, and there was a sharper decline in yields after the first year (lower residual effect of added N). Urea produced slightly higher yields than AN at the 100 and 200 kg N/ha rates, but lower yields at the 400 and 800 kg N rates. As at Scott lowest yields were obtained in 1980, a year with very low precipitation in April and May.

Annual protein yield trends (data not shown) were very similar to dry matter yields on both soils.

The total dry matter yield increases above the checks during the first four years for the one application and annual applications of N are shown in Figure 3. On both soils there was an increase in yield with increasing N rates up to 800 kg/ha. With better moisture conditions at the Loon River loam site average yields of bromegrass were higher, and yield increases were larger with increasing rates of applied N.

On Scott loam when N was applied once at 100 and 800 kg/ha, ureas and AN produced very similar total D.M. increases. At the 200 and 400 kg N/ha rates urea produced smaller increases. When a total of 200 kg N was broadcast, one-time and annual applications produced similar total yield increases, but urea was less effective than AN. At total rates of 400 and 800 kg N/ha annual applications gave substantially larger yield increases than one-time additions and AN produced approximately 1000 kg/ha more D.M. than urea. On the Loon River loam urea applied once at the 100 and 200 kg N/ha produced larger D.M. yield increases than AN at the same rates. At higher rates urea produced substantially lower yeilds than AN. When applied annually urea was less effective than AN at all rates on this soil. Differences between one-time and annual applications of N were less consistent than on Scott loam, and higher total yield increases were obtained from annual applications of urea and AN than from one-time additions only at the 800 kg N/ha rate. The 5-year total D.M. yield increase data showed similar patterns of response to the 4-year totals (Figure 4).

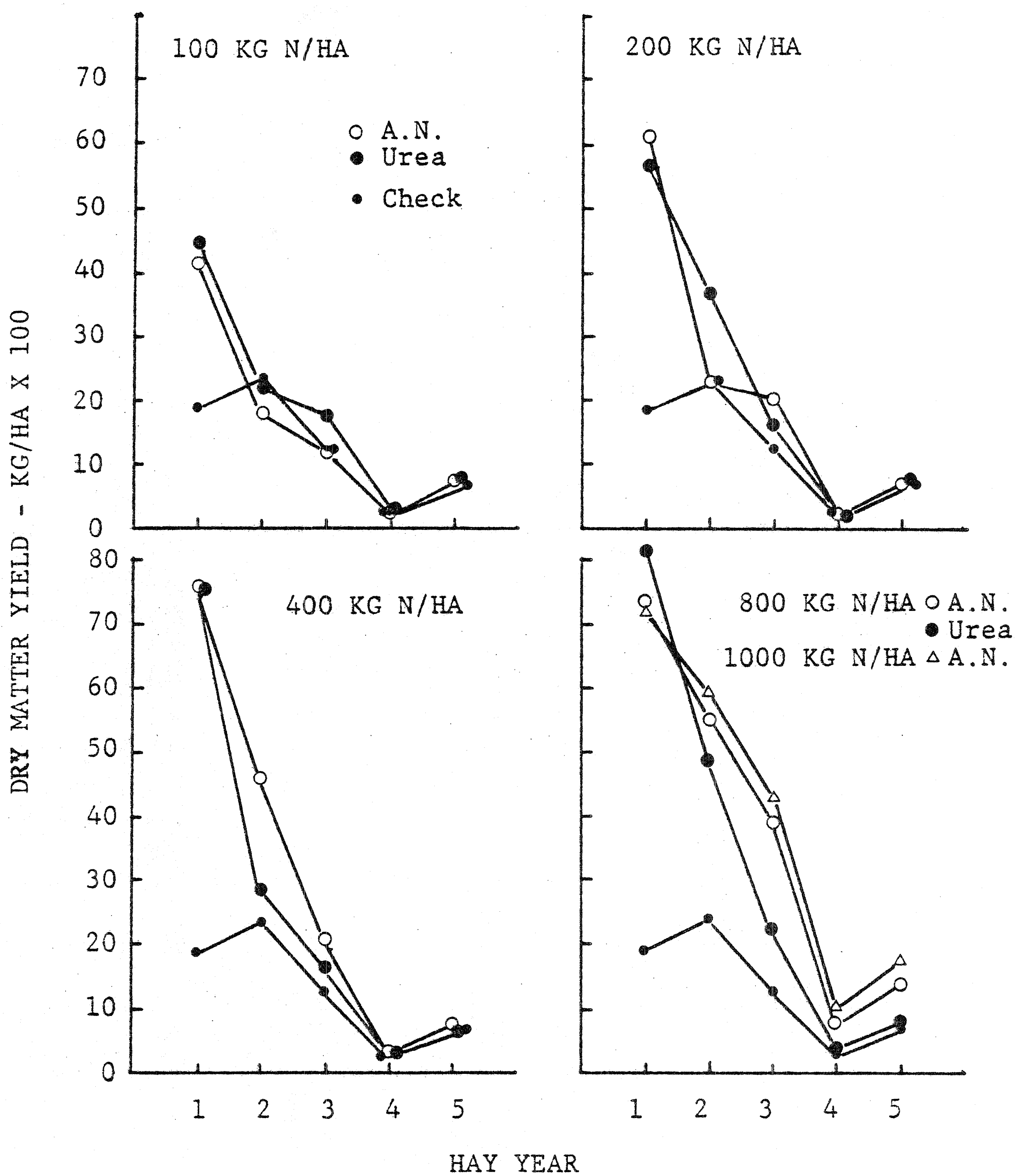

Figure 2. Effect of one broadcast application of ammonium nitrate and urea at several rates on annual yields of bromegrass hay over a 5-year period on Loon River loam (1977-81).

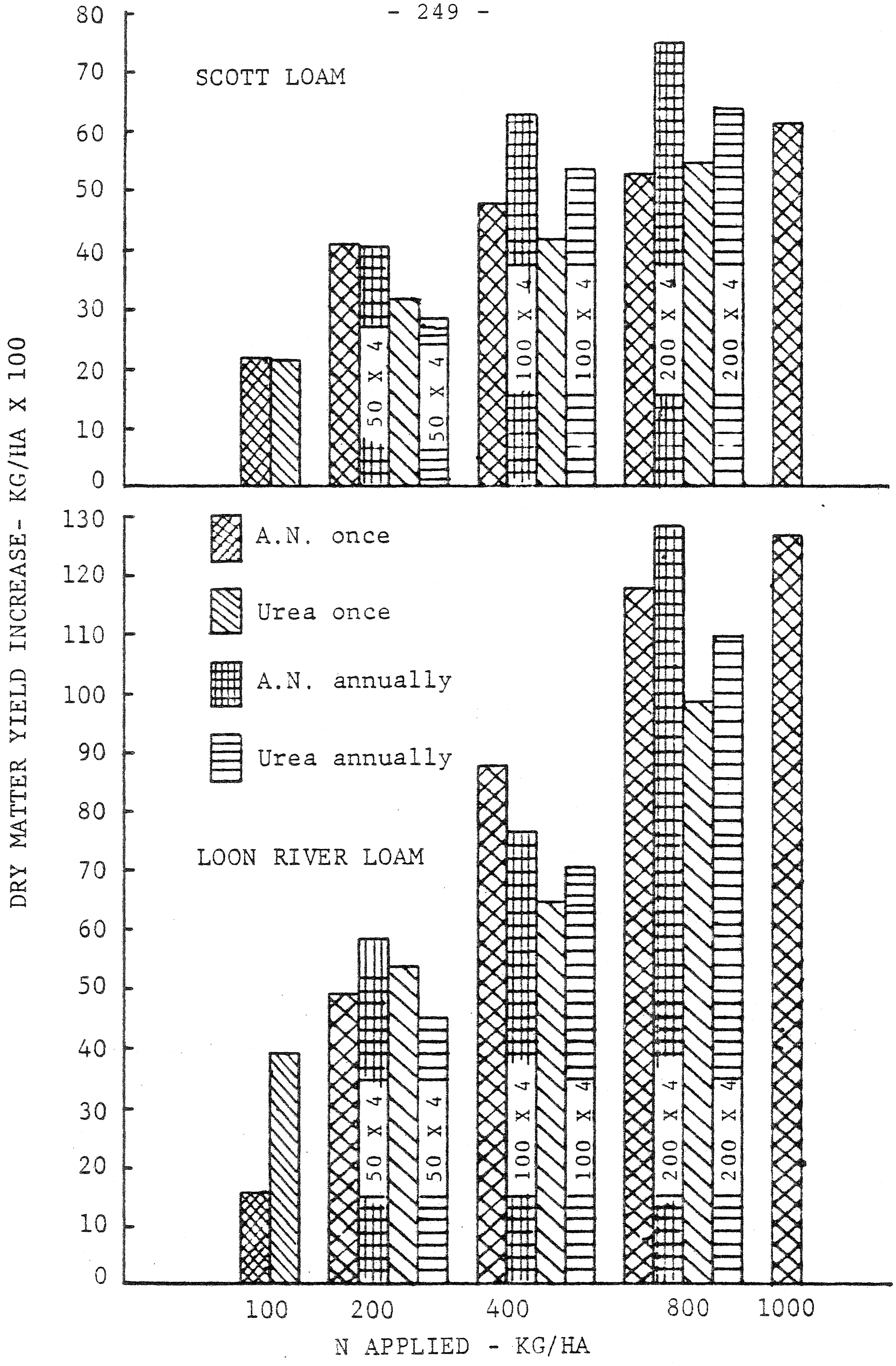

Figure 3. The effects of ammonium nitrate and urea broadcast once or annually on bromegrass over a period of 4 years on total dry matter yield increase above a non-fertilized check on two soil types.

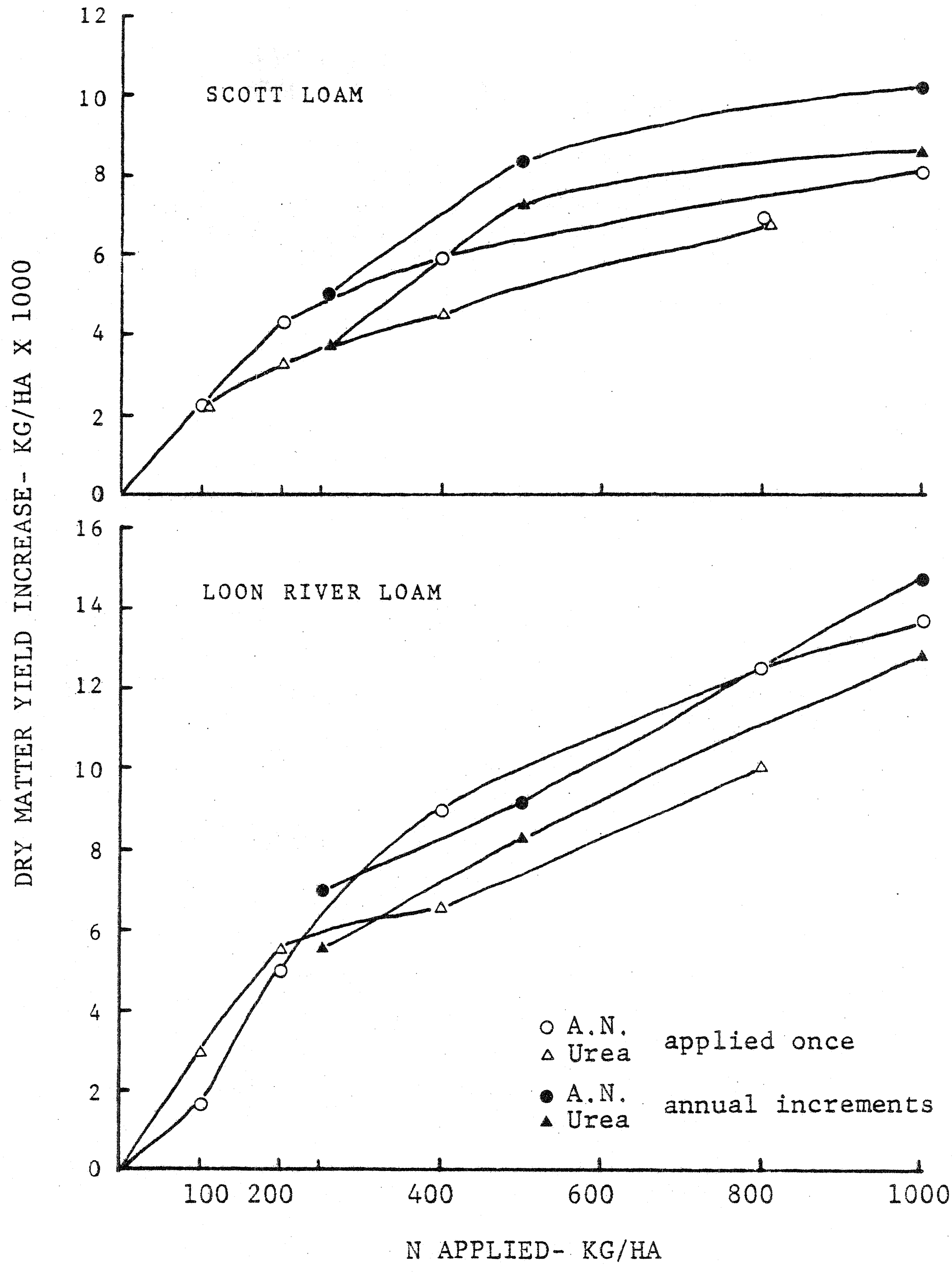

Figure 4. Effect of ammonium nitrate and urea broadcast once or annually on bromegrass on the 5-year total dry matter yield increases above an unfertilized check on two soil types.

Protein content and yield

Average protein contents in bromegrass at the flowering stage over the first 4 years of these experiments were lower on urea treated plots than on AN plots, for the one-time and annual applications, and the differences increased with increasing rates of N (Table 3). On an annual basis (data not shown) one-time surface application of N gave high protein contents in forage during the first year, with declining levels in subsequent years, while annual applications maintained relatively uniform protein contents. The total protein yield increases are shown for the

Table 3. Effect of N fertilizer on protein content in bromegrass hay on two soil types - 4 year average (1977-80).

	% Protein (O.D.B.)			
	Scott loam		Loon River loam	
N applied kg/ha	AN	Urea	AN	Urea
100 once	10.74	10.78	10.61	10.54
200 "	11.76	11.06	10.70	10.01
400 "	14.21	12.54	11.66	10.56
800 "	17.78	14.98	14.01	12.01
1000 "	15.65		13.84	
50 annually X4	10.34	10.37	9.91	9.72
100 " X4	12.64	12.03	10.62	10.08
200 annually X4	16.84	14.66	13.06	12.51
Check	10.03		11.51	

4-year period 1977-80, so that the cumulative totals of N applied annually can be directly compared with equal rates applied once at the beginning of the experiment (Figure 5). Protein yields increased with increasing rates of N similar to the D.M. yields, indicating that both yield and protein contents were increased as fertilizer N rates increased. Except at the 100 kg N/ha rates applied once, protein yield increases from urea were lower than from AN. Total protein yield increases from the one-time N treatments were equal to or higher than from the annual N applications on both soils, except for AN at 800 kg N/ha on Scott loam. The five-year total protein yields (data not shown) showed a similar response pattern.

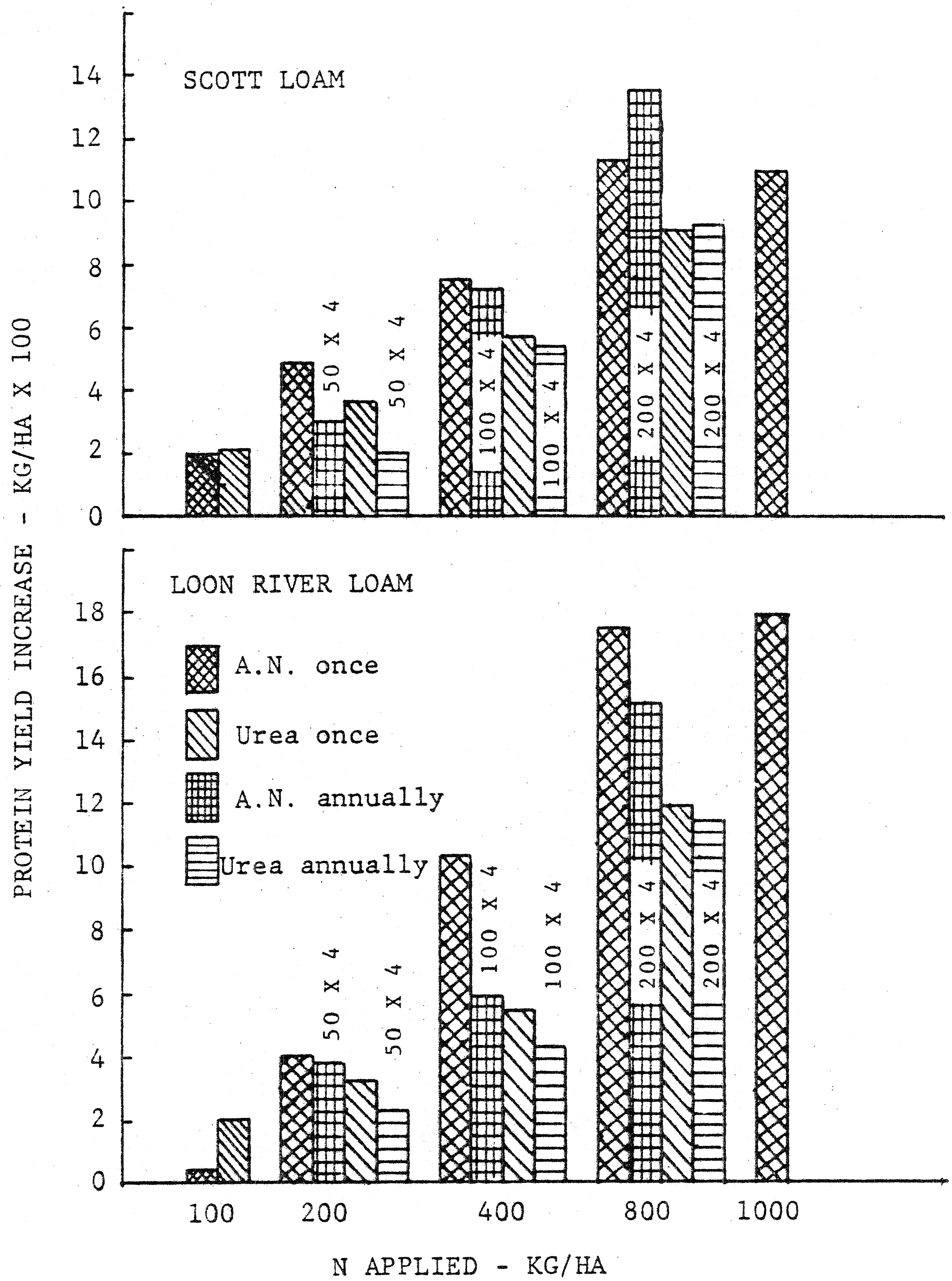

Figure 5. The effects of ammonium nitrate and urea broadcast once or annually on bromegrass over a period of 4 years on total protein yield increase above an unfertilized check on two soil types. -

NO_3-N in harvested hay

Nitrogen surface-applied at rates of 200 kg/ha or more produced potentially lethal levels of NO_3-N in bromegrass hay in the first year (Table 4). Levels of NO_3-N in hay were generally lower on urea plots than on AN plots. In the second year NO_3-N levels in bromegrass were markedly lower than in year one for all rates of N applied once, and only the 800 and 1000 kg N/ha rates increased NO_3-N to potentially hazardous levels. Urea or AN applied annually at up to 200 kg N/ha resulted in little or no increase in NO_3-N content of hay in the second year (1978).

Although one-time application of relatively high rates of N fertilizers appears to compare quite favorably to annual applications with respect to total D.M. and protein production over a period of several years on the Loon River soil, the results of the study show that this practice gives relatively high yields of grass during the first 1-3 years and low yields in subsequent years. This would not be a desirable yield pattern where sustained production is required. Furthermore, the potentially lethal levels of NO_3-N in the forage for several years following excessively high rates of N applied once would suggest that this is not a desirable practice. The effectiveness of urea is considerably lower than AN when applied once or annually at high rates on bromegrass on both soils. At the 800 kg N/ha total rate both urea and AN produced highest D.M. yields when applied in annual increments over a period of 5 years.

Table 4. Effect of N fertilizers on NO_3-N content in bromegrass hay on two soil types.

	% NO_3-N in dry matter							
	Scott loam				Loon River loam			
	1977		1978		1977		1978	
N applied kg/ha	AN	Urea	AN	Urea	AN	Urea	AN	Urea
100 once	.15	.15	.10	.10	.13	.15	.16	.17
200 "	.39	.34	.10	.10	.23	.13	.14	.15
400 "	.94	.40	.12	.12	.43	.66	.14	.16
800 "	1.58	.42	.52	.24	1.67	1.09	.33	.12
1000 "	.89		.44		1.41		.35	
100 annually X2			.11	.09			.15	.15
200 " X2			.15	.11			.16	.13
Check	.17		.09		.14		.16	

Recovery of applied N

Recovery of applied fertilizer N in harvested bromegrass over a 5-year period, calculated on the basis of:

$$\frac{\text{Total N in fertilized hay - Total N in unfertilized hay}}{\text{Total fertilizer N applied}} \times 100$$

ranged from 18.8% to 39.8% on Scott loam and 6.6% to 41.2% on Loon River loam for the various fertilizer treatments (Table 5). These recoveries are similar to those reported by Hanson, et al. (1978) and somewhat higher than those reported by Lutwick and Smith (1979). Except at the 100 kg N/ha rate applied once, recoveries of N from urea were lower than from AN at all rates of N applied once or annually on both soils, and recovery of N from one-time applications tended to decrease with increasing rates applied.

Table 5. Uptake of N from fertilizers in harvested bromegrass hay - 5 year total (1977-81).

N applied kg/ha	N uptake in hay - % of applied N[1] Scott loam		Loon River loam	
	AN	Urea	AN	Urea
100 applied once	34.2	35.2	6.6	32.3
200 " "	39.8	27.6	32.4	26.3
400 " "	34.0	23.6	41.2	21.3
800 " "	26.4	21.0	37.1	23.9
1000 " "	21.4		30.8	
50 annually X5	25.8	18.8	33.5	21.3
100 " X5	31.9	24.1	28.6	20.4
200 " X5	27.7	20.0	31.2	25.0
Check (total N uptake)	37.2		106.6	

[1] $$\frac{\text{Total N in fertilized plants - total N in check plants}}{\text{Total fertilizer N applied}} \times 100$$

Soil samples taken in the spring of 1981 to a depth of 60 cm prior to fertilizer application show a substantial accumulation of NO_3-N in plots which received 800 and 1000 kg N/ha as AN in one application on Scott loam (Table 6). Markedly lower levels of NO_3-N were found in the urea plots. These results give further evidence suggesting that large amounts of N may have been lost from the urea treated plots through NH_3 volatilization. The relatively low levels of NO_3-N in the Loon River soil plots suggest the possibility of leaching and denitrification losses of N under conditions of higher rainfall and poorer aeration in this soil, in addition to losses by NH_3 volatilization.

Table 6. Soil NO_3-N in bromegrass plots sampled prior to fertilizer application in spring, 1981 .

N applied kg/ha	NO_3-N - kg/ha Scott loam		Loon River loam	
	AN	Urea	AN	Urea
800 applied once	236	25	25	24
1000 " "	343		83	
200 annually X4	25	12	20	10

0-60 cm depth

Soil pH

Analysis of soil samples taken in the spring or 1981, prior to the spring fertilizer applications, show that substantial acidification of both soils occurred following the one-time and four annual broadcast applications of urea and ammonium nitrate (Table 7). On Scott loam only the urea plots were sampled for pH determination. Although some variability is evident in the pH data, urea applications lowered soil pH by as much as 0.7 units on Scott loam, and the lowest pH levels resulted from the annual N applications. With the annual applications of urea, pH was lowest in the 7.5-15 cm depth, with apparent acidification in the 15-30 cm depth also.

On the Loon River soil lowest pH levels were found in the 0-7.5 cm depth, with a maximum depression of 0.9 pH units, and the one-time applications of ammonium nitrate and urea lowered pH slightly more than annual applications. The pH levels were generally lower on AN than on urea plots, probably indicating a greater loss of N through NH_3 volatilization and less NH_4 available for nitrification. This possibility has been suggested by other workers (Fox and Hoffman 1981). The pH of the soil from the check plots suggests that some acidification has occurred under a long-term bromegrass even without N fertilizers on the Loon River soil.

A deterioration of bromegrass stands and encroachment of other species has necessitated the dicontinuation of the experiment on the Scott loam soil. The study will be continued on the Loon River soil and annual soil sampling will be carried out for determination of N accumulation and pH changes.

Table 7. The effect of N fertilizers applied to bromegrass on two soil types over a 4-year period on soil pH.

N applied kg/ha	pH ($CaCl_2$)* 0-7.5 cm AN	0-7.5 cm Urea	7.5-15 cm AN	7.5-15 cm Urea	15-30 cm AN	15-30 cm Urea
			Scott loam			
200 applied once	5.05		5.15		5.50	
400 " "	5.65		5.90		6.75	
800 " "	5.05		5.00		5.70	
50 annually X4	5.10		4.80		5.05	
100 " X4	5.40		5.00		5.20	
200 " X4	4.95		4.80		5.20	
Check	5.50		5.50		5.80	
			Loon River loam			
200 applied once	5.00	5.00	5.65	5.65	5.85	6.00
400 " "	5.40	5.35	6.25	5.90	6.50	6.10
800 " "	4.40	4.95	5.30	5.60	6.15	6.05
1000 " "	4.80		5.85		6.30	
50 annually X4	5.50	5.60	6.00	6.30	6.20	6.30
100 " X4	5.15	5.45	6.05	6.05	5.90	6.20
200 " X4	4.60	5.40	6.25	6.05	6.50	5.90
Check	5.80		6.10		6.35	

* 1:2 soil/0.01 M $CaCl_2$

REFERENCES

BURTON, G.W. and JACKSON, J.E. 1962. Effect of rate and frequency of applying six nitrogen sources on Coastal bermudagrass. Agron. J. 54: 40-43.

CAIRNS, R.R. 1971. Changes in a solonetzic soil caused by the long-term heavy fertilization of bromegrass. Can. J. Soil

Sci. 51: 299-301.

DEINUM, B. and SIBMA, L. 1980. Nitrate content of herbage in relation to nitrogen fertilization and management. Proc. Int. Symp. Eur. Grassland Fed. on the role of nitrogen in intensive grassland production, Wageningen, 1980. pp. 95-102.

FOX, R.H. and HOFFMAN, L.D. 1981. The effect of N fertilizer source on grain yield, N uptake, soil pH, and lime requirement in no-till corn. Agron. J. 73: 891-895.

GASSER, J.K.R. 1973. An assessment of the importance of some factors causing losses of lime from agricultural soils. Exp. Husb. 25: 86-95.

HOYT, P.B. and HENNIG, A.M.F. 1982. Soil acidification by fertilizers and longevity of lime applications in the Peace River region. Can. J. Soil Sci. 62: 155-163.

JOLLEY, von D. and PIERRE, W.H. 1977. Soil acidity from long-term use of nitrogen fertilizer and its relationship to recovery of the nitrogen. Soil Sci. Soc. Amer. J. 41: 368-373.

LAMOND, R.E., MURPHY, L.S., SWALLOW, C.W. and KELLEY, R.W. 1979. Comparative performance of nitrogen source on smooth bromegrass and tall fescue. Soil Sci. Soc. Amer. J. 43: 610-612.

LEYSHON, A.J. and KILCHER, M.R. 1977. Effects of a single large application of fertilizer upon the subsequent ten-year yields of three grasses. Paper presented at the 1977 Annual Meeting of the Canadian Soc. Agron., August 14-18, Guelph, Ont.

LUTWICK, L.E. and SMITH, A.D. 1979. Yields and N uptake by seven perennial grass species as affected by high rate of N fertilizer. J. Range Management 32(6): 433.

McCOY, D.A. and WEBSTER, G.R. 1977. Acidification of a Luvisolic soil caused by low-rate, long-term applications of fertilizers and its effects on growth of alfalfa. Can. J. Soil Sci. 57: 119-127.

MEYER, D.W., CARTER, J.F. and VIGIL, F.R. 1977. Bromegrass fertilization at six nitrogen rates: Long and short term effects. Farm Research 34(6): 13-17. North Dakota Agric. Exp. Station.

POWER, J.F. ALESSI, J., REICKMAN, G.A. AND GRUNES, D.L. 1972. Effect of nitrogen sources on corn and bromegrass production, soil pH, and organic soil nitrogen. Agron. J. 64: 341-344.

POWER, J.F. 1974. Urea as a nitrogen fertilizer for Great

Plains grasslands. J. Range Management 27(3): 161-164.

SIMPSON, J.R. 1968. Losses of urea nitrogen from the surface of pasture soils. 9th Int. Congress of Soil Sci. Transactions, Volume II: 459-466.

SMITH, A.D. and LUTWICK, L.E. 1974. Effect of N fertilizers on total-N and NO_3-N content of six grass species. Can. J. Plant Sci. 55: 573-577.

SMITH, C.J. and CHALK, P.M. 1980. Comparison of the efficiency of urea, aqueous ammonia and ammonium sulphate as nitrogen fertilizers. Plant and Soil 55: 333-337.

TERMAN, G.L. 1979. Volatilization losses of nitrogen as ammonia from surface-applied fertilizers, organic amendments, and crop residues. Adv. Agron. 31: 189-223.

TESAR, M.B. 1978. Productivity of three grasses fertilized with ammonium nitrate or urea. Michigan Agr. Exp. Sta. Res. Report 353: 13-20.

UKRAINETZ, H. 1969. Forage crop fertilization - Eastern Prairies. In Proc. Canadian Forage Crop Symposium, 1969. pp. 187-221.

VOLK, G.M. 1959. Volatile loss of ammonia following surface application of urea to turf or bare soil. Agron. J. 51: 746-749.